A Study on Corrossion Control of Reinforcing Steel in Concrete Containing Salt

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1. INTRODUCTION

The corrosion of reinforcing steel in the concrete containing salt occurs and progresses rapidly even in the case that the concrete around reinforcing steel is not carbonated and keeps alkalinity. Many attempt to arrest the progress of corrosion of reinforcing steel in the concrete containing salt has been done, and it is found that the corrosion inhibitor permeated into the concrete is most useful to control the corrosion of reinforcing steel. It is also found that the method how to permeate the corrosion inhibitor is difficult to be developed, because the corrosion inhibitor should be permeated to the place where the reinforcing steel exist and the enough concentration of corrosion inhibitor should be kept for many years. We have terminated experimental study on this problem and developed an effective method that the corrosion inhibitor is applied by brush on the concrete surface in combination with alkalizing agent and rustproof paste.

2. EXPERIMENTAL METHOD

2.1 Subject of Experiment

A reinforced concrete wall forming a part of a swimming pool of a high school in Oita Prefecture was used in the experiment as a reinforced concrete structure containing salt. The experiment was conducted on an exposed surface of the concrete wall one-half meter high facing north-north-west. This reinforced concrete structure was built in 1972 and 13 years has passed at the beginning of the experiment.

In the preliminary test, the compressive strength, the carbonation depth and salt content of the concrete wall were examined. The compressive strength measured with a Schmidt hammer on dry concrete surface was averaged 282kgf/cm^2 as conversion of the column specimen. The carbonation depth measured on the core extracted from the concrete wall averaged about 17mm. Fig. 1 shows the salt content analyzed on the test material obtained by crushing the concrete core into fine pieces. The peak of salt content is seen at the depth of about 30mm from the concrete surface, and the overall concentration of salt is around 0.1%. It is considered that sea sand containing salt exceeding 0.3% concentration was used in

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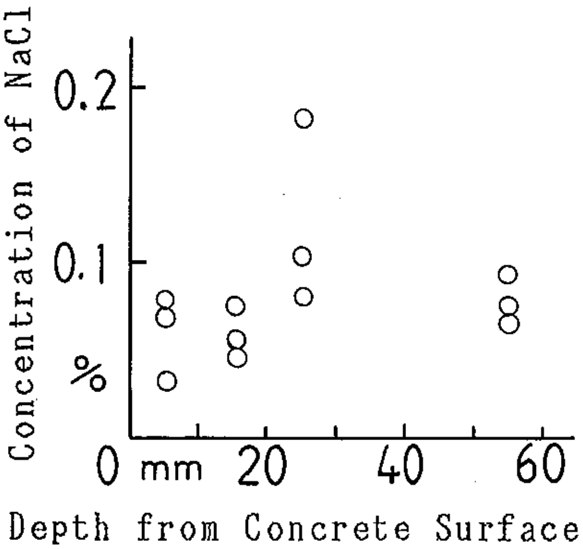

Fig. 1

the concrete construction without removing its salt content.

2.2 Materials and its Specifications

The materials used are shown in Table 1. The corrosion inhibitor considered having good permeability into concrete was chosen. Specifications of applied corrosion inhibitor are shown in Fig. 2. There are four types of specifications and they are the combinations of a process in which alkalinity is given to the base concrete prior to the application of corrosion inhibitor and a process to cover the surface with rustproof paste after the application of corrosion inhibitor. These specifications are represented by marks of E, F, G and H.

Table 1 Materials

Materials	Main Ingredients
Corrosion Inhibitor	Calcium Nitrite + Additives
Alkalizing Agent	Lithium silicate + Additives
Rustproof Paste	Normal Portland Cement Synthetic Rubber Latex Calcium Nitrite

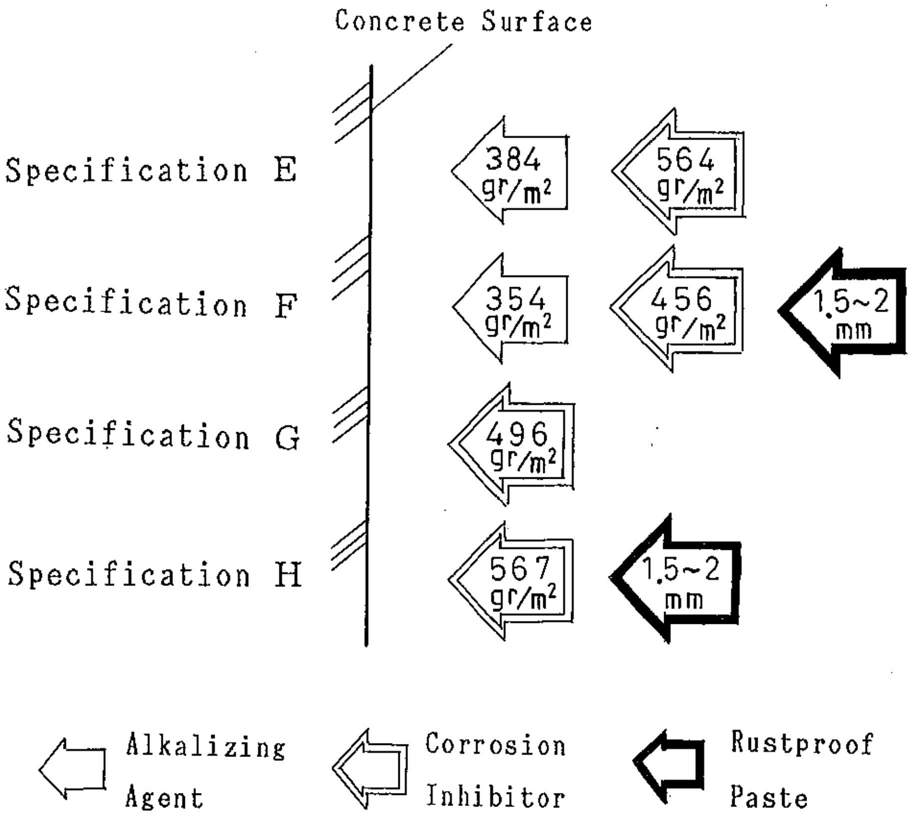

Fig. 2

2.3 Application

The application of corrosion inhibitor was done on April 1985. The tested concrete wall surface was laid out in areas of 90x100cm for each specification. The concrete surface was rubbed hard with dry cloths to remove stains, then water-washed. Applications were performed according to specifications in Fig. 2. The applied amount in each specification are shown in Fig. 2. In the specifications E and F five hours were left between the application of alkalizing agent and the application of corrosion inhibitor. In the specifications F and H the rustproof paste was trowel-applied twice on the concrete surface to achieve a final thickness of 1.5mm-2.0mm.

2.4 Specimens and Analysis Method

The concrete cores of 65mm in diameter were extracted from the concrete wall for each type of specification at the periods of 7 days, 1 month, 3 months, 6 months, 1 year and 2 years after the date of corrosion inhibitor application. The number of concrete cores of each period and specification is two. To prepare specimens, concrete cores were cut as shown in Fig. 3 and they were crushed into

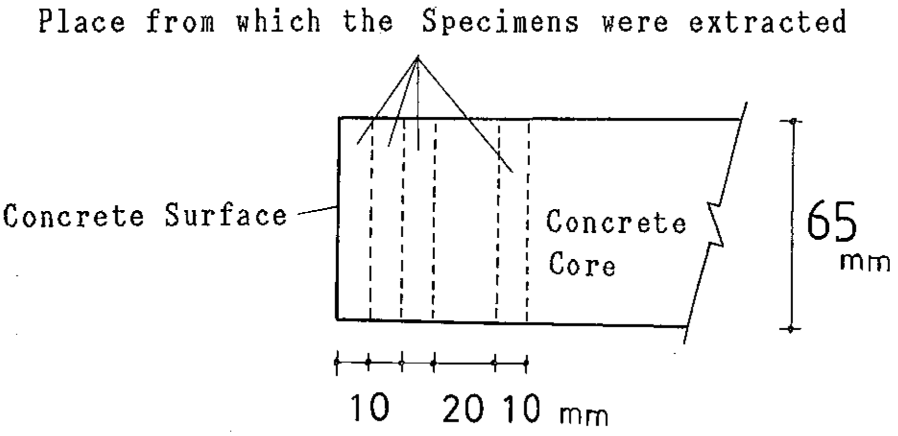

Fig. 3

fine pieces passing a sieve of 149μm. Four specimens were made from each core, three of them were taken from three layers each one centimeter deeper from the concrete surface and the other was 5cm-6cm deep from the concrete surface. To estimate the content rate of the corrosion inhibitor quantitative analysis on nitrite ion (NO_2 ion), the main ingredient of the corrosion inhibitor, was conducted by naphthylamine absorptiometric method.

3. RESULT AND OBSERVATIONS

Figs. 4 through 7 indicate the relations between the analyzed concentration of NO_2 ion and the age for each type of specification. The concentration of NO_2 ion taken on the vertical axis represents the concentration of the corrosion inhibitor which permeated into the concrete with the age.

In every Fig. 4 through 7 the white circle, which is the analyzed result of the depth of 0cm-1cm from the concrete surface, shows very high concentration just after the application of the corrosion inhibitor, thereafter with the lapse of time the concentration of corrosion inhibitor decreases. The analyzed result of the depth of 5cm-6cm from the concrete surface, represented by black circle, slightly increases with the age. In the meantime, the analyzed result of concentration of NO_2 ion in the case of nontreatment where no corrosion inhibitor was applied is less than 0.001%. From these, it can be observed that the corrosion inhibitor which is put on the concrete surface by brush diffuses and permeates into the concrete.

Figs. 4 and 6 show the analyzed results of specifications E andG in which rustproof paste was not applied after the application of corrosion inhibitor. There the concentration of corrosioninhibitor decreases overall as the age grows. This is because thecorrosion inhibitor put on the concrete surface is emitted and lost from the concrete surface to the environment.

Figs. 5 and 7 show the analyzed results of the specifications F and H in which rustproof paste was put on the concrete surface after the application of corro-

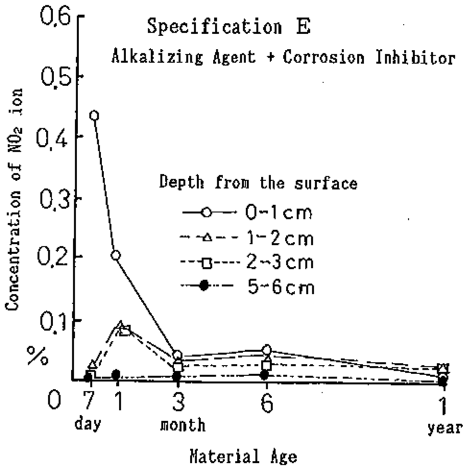

Fig. 4 Specification E

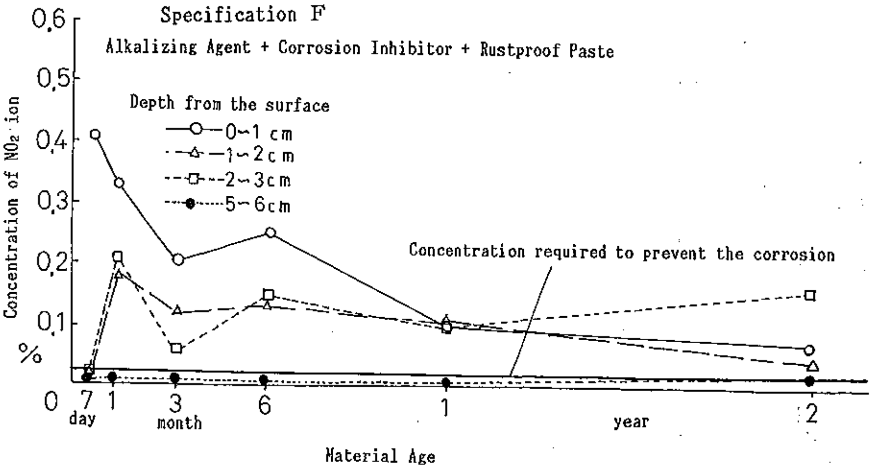

Fig. 5 Specification F

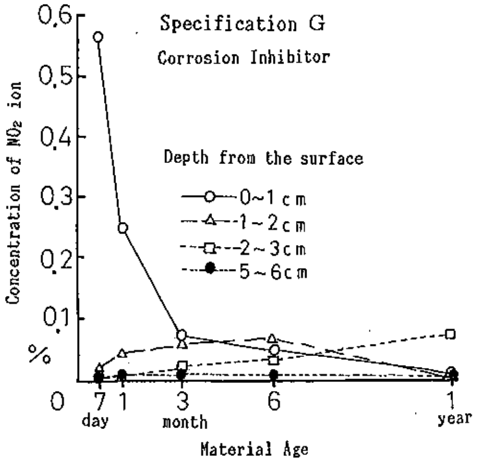

Fig. 6 Specification G

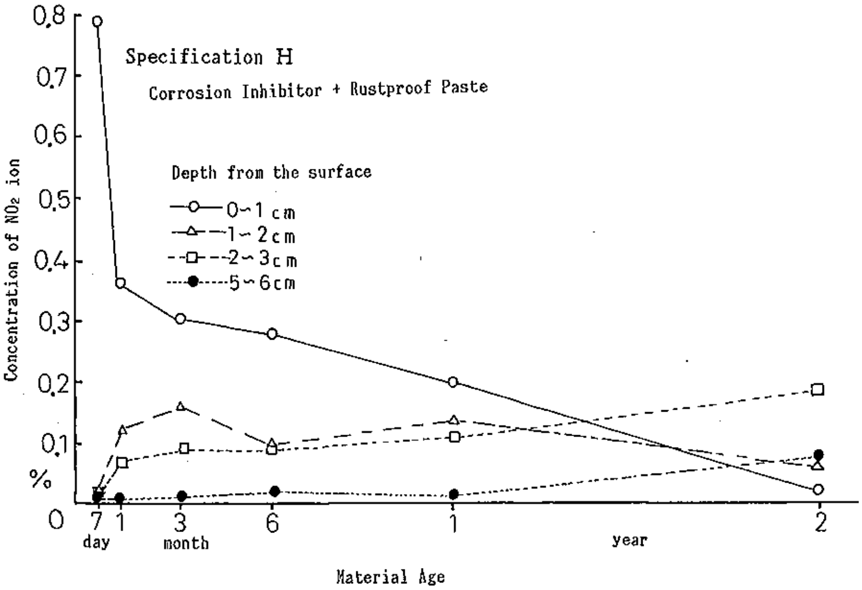

Fig. 7 Specification H

sion inhibitor. The corrosion inhibitor of a considerable concentration permeated to the depth of 0cm-3cm from the concrete surface already at the age of 1 month. In these cases the concentration of corrosion inhibitor is kept high even after the age grows and the quantity of the corrosion inhibitor which is emitted and lost from the concrete surface to the environment is small.

4. CORROSION CONTROL

According to a study¹⁾ using the method of salt water immersion test for reinforcing steel in JIS A 6205, the quantity of corrosion inhibitor required to control the progress of corrosion of reinforcing steel is 0.017% in conversion of NO_2 ion concentration when the quantity of chloride ion in concrete is 600gr/m^3, and 0.02% to 0.025% when the quantity of chloride ion in concrete is in the range between 1000gr/m^3 and 3000gr/m^3.

For the concrete wall on which the experiment was conducted in this study, the contained quantity of chloride ion is around 1000gr/m^3 and the quantity of corrosion inhibitor required to prevent the progress of corrosion of reinforcing steel amounts to 0.02% in conversion of NO_2 ion concentration. In Fig. 5 the required quantity of corrosion inhibitor in conversion of NO_2 ion concentration is indicated by a horizontal line. After two years passed, the concentration of corrosion inhibitor in the case of specification F indicated by NO_2 ion concentration is 0.02% to 0.2% which is effective to prevent the corrosion of reinforcing steel. It is observed that the application of corrosion inhibitor onto a concrete surface by the method of specifications F has the possibility to make the quantity of corrosion inhibitor permeated into the concrete sufficient to control the corrosion of reinforcing steel.

5. CONCLUSION

The corrosion inhibitor applied on the concrete surface by brush permeates into the concrete or is emitted and lost from the concrete surface to the environment. To prevent the corrosion inhibitor from being emitted and lost from the concrete surface, the specification F in which the alkalizing agent is first applied and the rustproof paste is put on the concrete surface after the application of corrosion inhibitor is effective. By this method it is possible to get the enough concentration of corrosion inhibitor permeated into the concrete to arrest the corrosion of reinforcing steel as far as the depth of several centimeters from the concrete surface.

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